TITAN AEROVER AUTONOMOUS OPERATION AND BIO-DETECTION

Interim or Final Report

JPL Task 1013

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A. OBJECTIVES

Titan, the largest moon of Saturn, is the only moon in our solar system with a significant atmosphere, and it happens to be ideally suited for balloon exploration. The nitrogen atmosphere has a pressure a bit higher than that of Earth, and it is much colder at -180^{o}C (Reference 1). This makes the density of the atmosphere four times as much as that on Earth, and thus helium balloons can carry four times as much payload. Titan is believed to have large solid landmasses and cold, liquid hydrocarbon oceans (Figure 1). It was once as warm as the Earth, with liquid water oceans, and is considered to be ideal for blimp surface and higher-altitude science investigations (Figure 2) if blimp autonomy and sample gathering can be demonstrated. The objectives of this DRDF task are to modify a commercial blimp to demonstrate autonomous travel to various indoor and outdoor targets using GPS as well as color-coded bio-signature-seeking navigation systems. The blimp is to be used to gather organic surface samples at an outdoor location, followed by testing of the collected surface samples.

B. PROGRESS AND RESULTS

A number of balloon autonomous-mobility experiments have been successfully performed during this task. In the first experiment, simple autonomous travel was demonstrated with a small commercial 2.3-m (7.5-feet) blimp that was outfitted with a GPS transponder navigation system originally produced for model airplanes. The blimp was specially fabricated with a simple control system consisting of two front-facing propellers for basic forward-reverse propulsion, one tail propeller for turning, and one downward facing propeller for altitude control. The slow blimp speed of less than 3 m/sec (6.75 MPH) made travel between GPS waypoint locations difficult to control, and thus a magnetic-bearing compass system was added. Although Titan does not have a magnetic field or a GPS satellite system, these control systems helped to determine that the propulsion system selected was able to precisely travel a pre-determined route with reasonable accuracy. Thus, this combination of propulsion systems can be used for various other autonomous aerobot mobility systems.

A second autonomous operation system was then configured so as to send the small blimp to a specific color-coded target, which was chosen from among various colors including red, blue, and chlorophyll-colored green leaves. For these tests, a color video camera was set in the nose of the blimp gondola, and an automatic tracking system was fabricated to keep the tracked color in the center of the video image. The blimp was set to travel forward at a fixed altitude, with the tail propeller compensating for deviating winds by turning the blimp and keeping it on track. These tests initially resulted in overcompensation of turning with the targeted image falling outside of the video-directing camera. When the tail motor speed was reduced, however, accurate tracking resulted for all targets.

The next autonomous operation demonstrated was a hovering algorithm for maintaining the blimp above a specific target. For this demonstration, an algorithm was created and demonstrated such that the tail propeller kept the image in the center from right to left, and the forward/reverse propellers kept the image in the center from front to back. A four-camera coordinated system was employed, which allowed a 120-degree by 120-degree view directly below the blimp. This simple, dual-control algorithm was shown to function well to keep the targeted image in the center of the four-camera system.

To demonstrate the blimp's ability to collect ground samples, a small, hollow grated cylinder (Figure 3, top left) was fabricated and radio-deployed to descend and ascend while the blimp was flying at a fixed altitude above a lake (Figure 3, right). A number of lake and lake-bottom samples were collected while the blimp was flown over various beach and lake areas (Figure 3, bottom left). The samples were then stored in biologically clean containers and frozen. Titan-like scientific tests, such as GCMS (gas chromatograph-mass spectrometer) microscopic evaluation, and biota determination are planned for the samples.

C. SIGNIFICANCE OF RESULTS

The viability of a miniature blimp scientific investigation of Titan is significantly increased by these demonstrations of autonomous tracking and hovering, as well as by the demonstration of ability to gather ground samples while flying. A simple control configuration of forward/reverse propulsion, tail-propeller turning, and upward/downward propulsion has demonstrated that autonomous navigation between various waypoints can be readily accomplished, as demonstrated by the GPS/magnetic-heading waypoint system.

The color-coded tracking tests further confirmed that small blimps could lock onto an optical signature and proceed to that object, and then maintain hovering above the object. The radio-controlled, tethered surface sampler performed well during all over-ground and over-lake operation tests. One significant finding was that it was necessary to hover over a single point on the lake during the entire time that the 18-gram sampler was lowered to the lake bottom. Any significant motion of the blimp caused the lightweight sampler to drag back up towards the surface of the lake.

D. FINANCIAL STATUS

The total funding for this task was $100,000 of which approximately $90,000 has been expended.

E. PERSONNEL

Other personnel working on this study include Jiunn Jeng Wu of JPL (image targeting and hovering) and Dave Wakeman of MicroPilot Corporation (GPS and magnetic heading operation).

F. PUBLICATIONS

[1] Jack A. Jones and Ralph Lorenz, "Titan Aerover All-Terrain Vehicle," Space Technology and Applications international Forum (STAIF-2002), Albuquerque, NM, February, 2002.

[2] Jeffery L. Hall et al, "Titan Airship Explorer," IEEE Aerospace 2002 Conference, Big Sky Montana, March 2002.

[3] Jack A. Jones, "Aerover Development at JPL/NASA," *SPIE Unmanned Ground Vehicle Technology video Session*, Orlando, Fl, 2002, JPL Video #2002_01_02.

[4] JPL Titan Aerover URL: http://www.jpl.nasa.gov/adv_tech/balloons/summary.htm

G. REFERENCES

[1] Ralph Lorenz, "2000 Post-Cassini Exploration of Titan: Science Rationale and Mission Concepts," *Journal of the British Interplanetary Society*, Vol. 53, pp. 218-234, 2000.

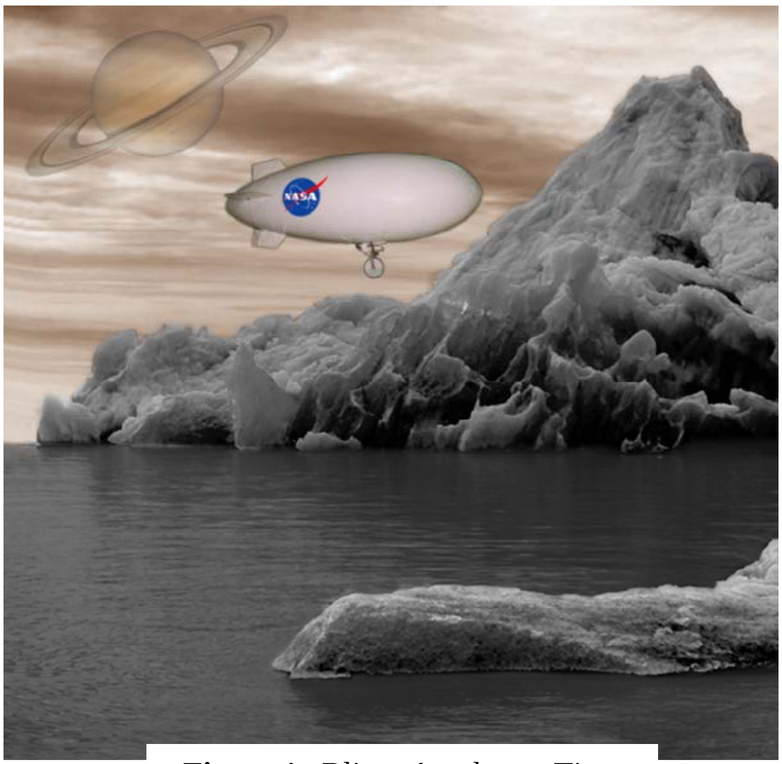

Figure 1. Blimp Aerobot at Titan

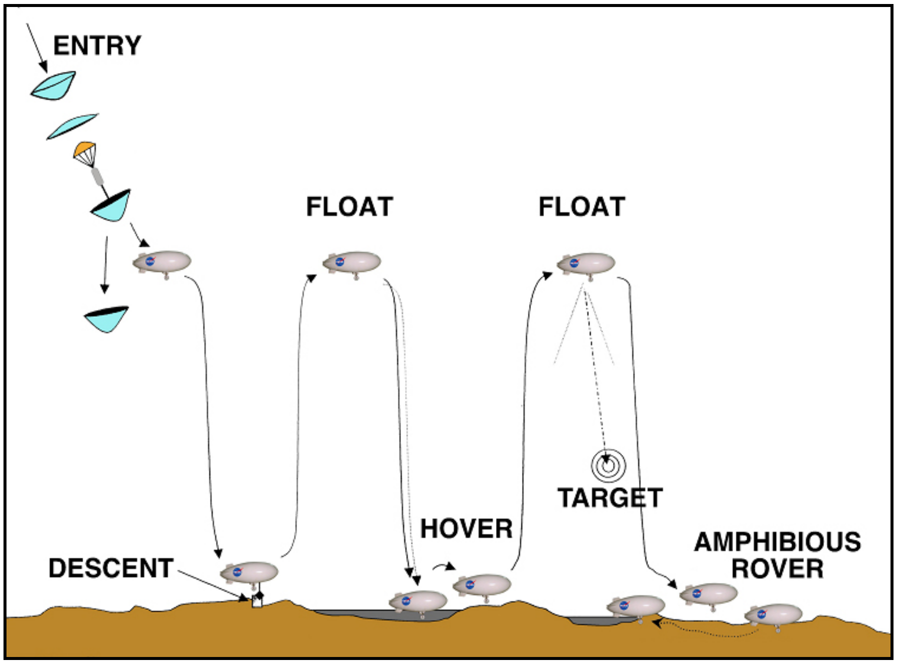

Figure 2. Titan Aerobot Mission Sequence

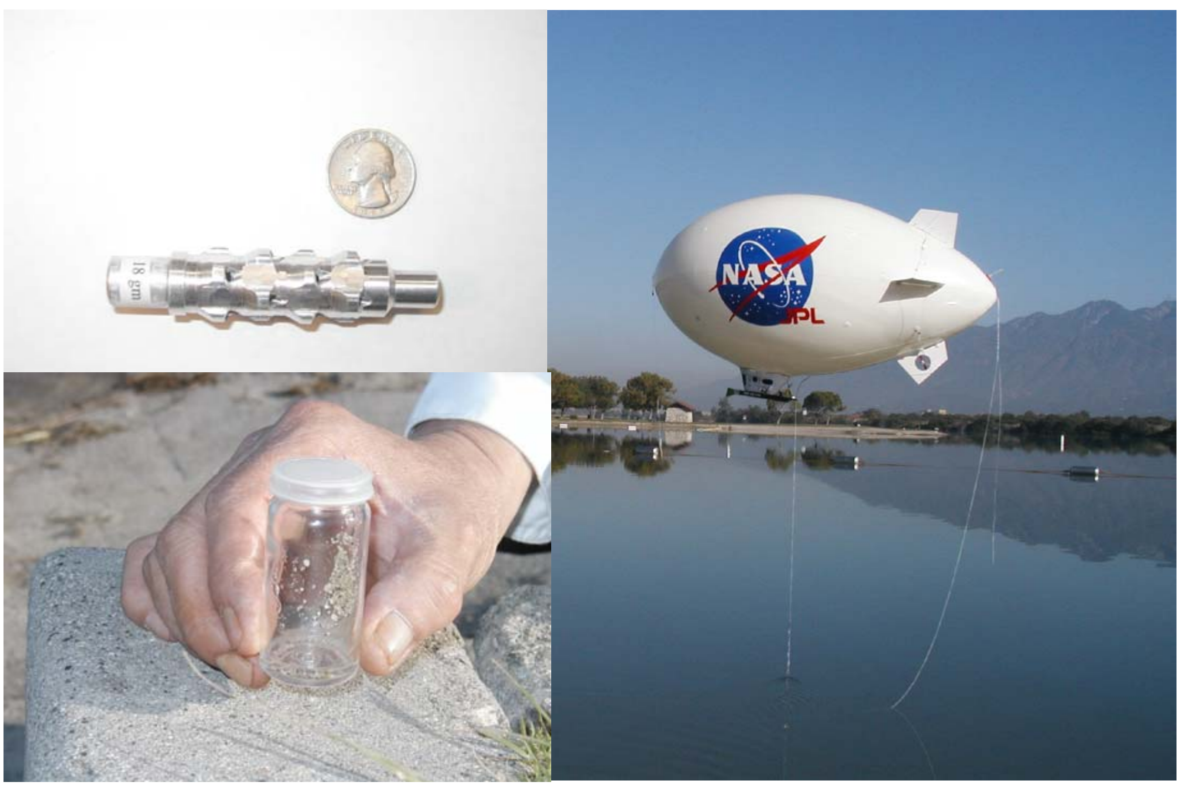

Figure 3. Clockwise from Top Left: 18-gram Perforated Grated Surface Sampler, Blimp Sampling Tests of a Lake Bottom, Collected Surface Sample Material